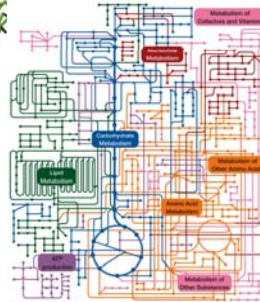
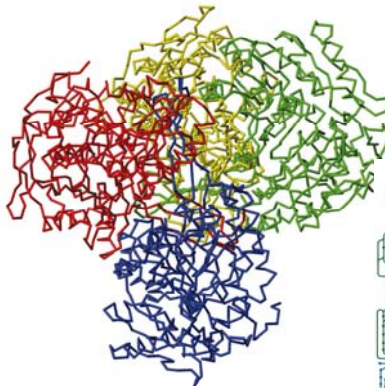


Energy, Enzymes & Metabolism



LIFE Ch. 8



Some definitions

- **Energy:** ability to carry out work
- **Enzymes:** Protein molecules that function as catalysts
- **Metabolism:** All chemical transformations in an organism



Energy - the ability to carry out work

- Energy can be converted from one form to another



light
heat



potential
kinetic

electric
light
heat



potential



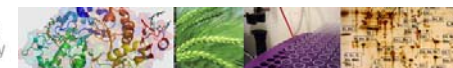
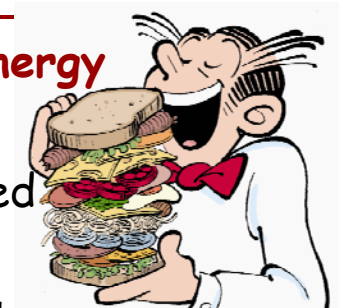
chemical



Energy - the ability to carry out work

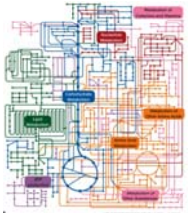
chemical energy = potential energy

- Potential energy can be stored or released
- In biochemistry: energy can be released in the form of e.g. nerve impulses, muscle contraction, heat



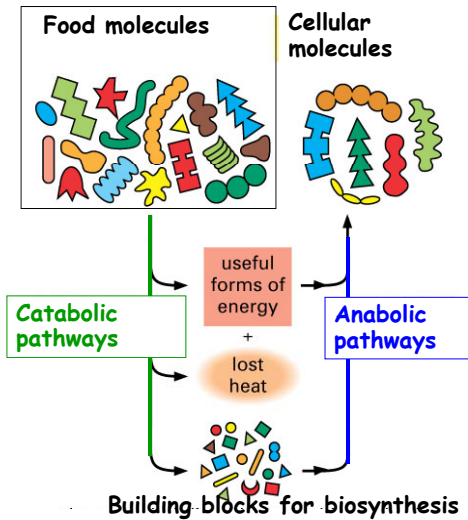
Metabolism

- Chemical transformations
= **catabolism** + **anabolism**



Anabolism: building up

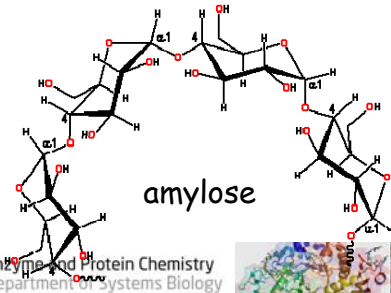
Catabolism: breaking down



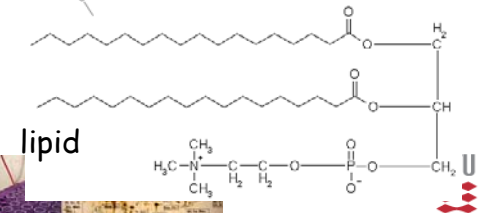
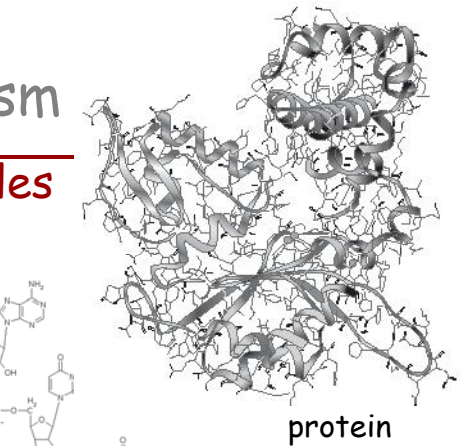
Anabolism

- **Synthesis of biomolecules**

- Lipids
- Amino acids/proteins
- Nucleic acids
- Carbohydrates

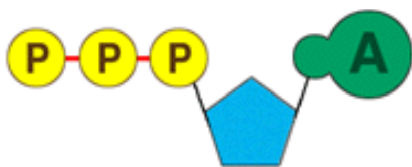


RNA

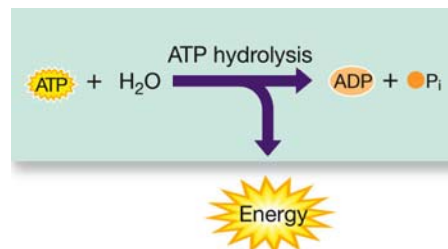


Catabolism

- Molecules are broken down to smaller molecules
- Often releases chemical energy

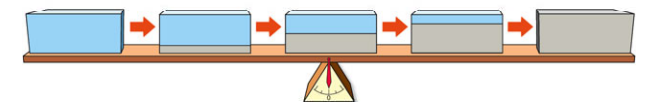
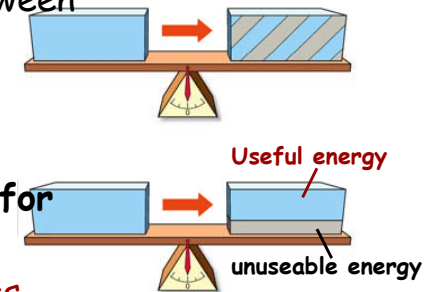


Adenosine triphosphate



Thermodynamics

- Energy can be converted between different forms
- **Energy is conserved**
First law of thermodynamics
- **Not all energy can be used for work**
Second law of thermodynamics
Entropy increases : $\Delta S > 0$



Free Energy

All energy unuseable energy

$$H = G + TS$$

Gibbs Free energy

During a chemical transformation:

$$\Delta G = \Delta H - T\Delta S$$

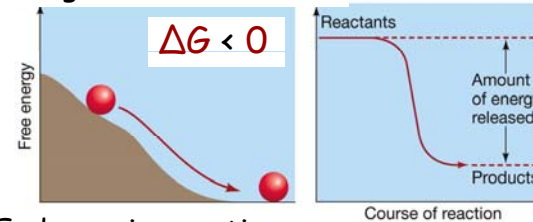
Spontaneous chemical reactions release chemical energy (are **exergonic**)

ie ΔG is negative



Chemical Equilibrium

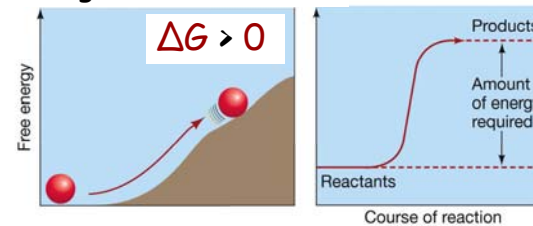
Exergonic reaction



Chemical reactions are reversible



Endergonic reaction



At equilibrium:

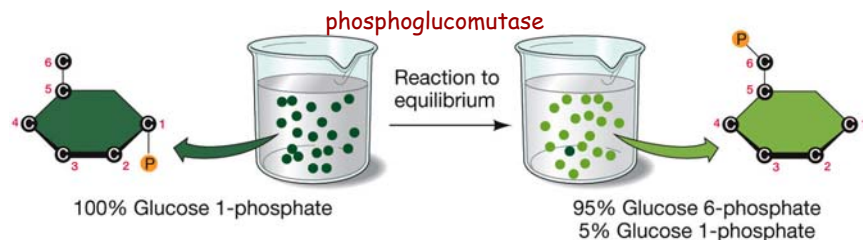
$$\Delta G = 0$$



Chemical equilibrium is determined by ΔG

ΔG depends on:

- the characteristic ΔG^0 for the reaction
- concentrations of reactant and product

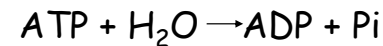


The reaction can run in either direction

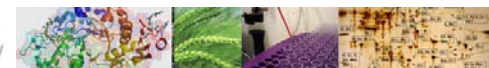
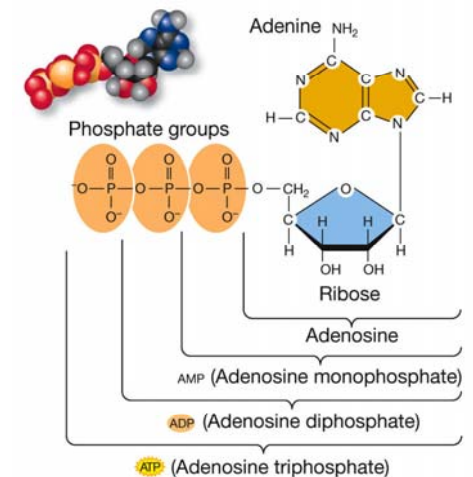
The reaction continues until equilibrium, $\Delta G = 0$



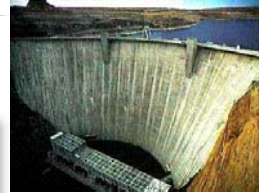
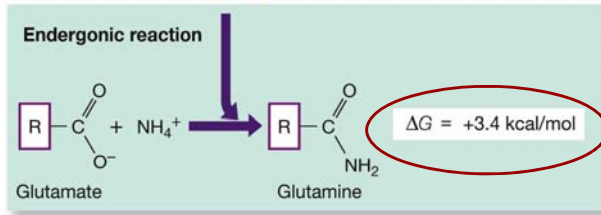
Adenosine triphosphate is the "energy currency" of the cell



$$\Delta G = -30 \text{ kJ mol}^{-1}$$



Endergonic and exergonic reactions can be coupled



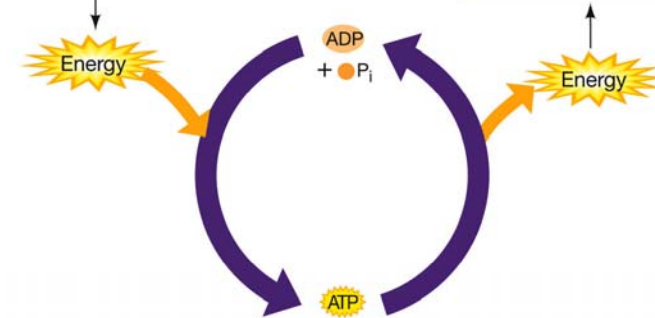
ATP recycling

Exergonic reaction:

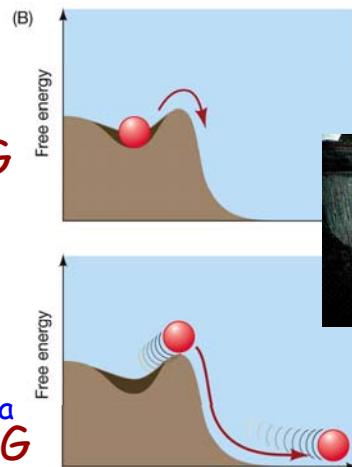
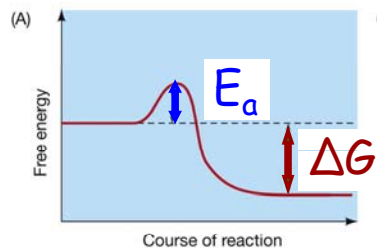
- Cell respiration
- Catabolism

Endergonic reaction:

- Active transport
- Cell movements
- Anabolism



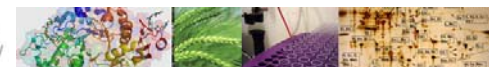
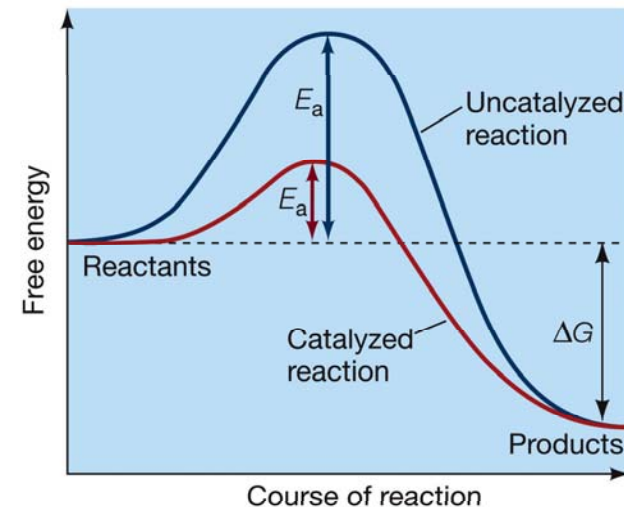
An energy barrier must be overcome, before a reaction can run



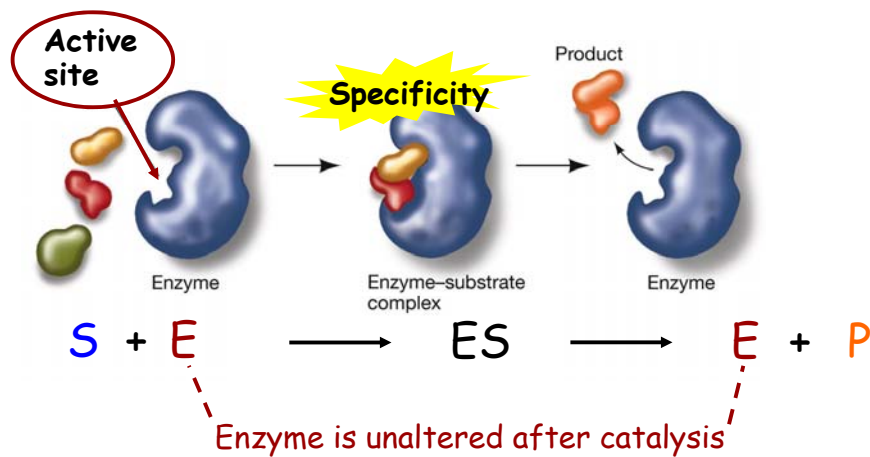
Activation energy E_a is **independent** of ΔG



Enzymes catalyse reactions by lowering the activation energy



Activation energy is lowered by bringing reactants close to each other

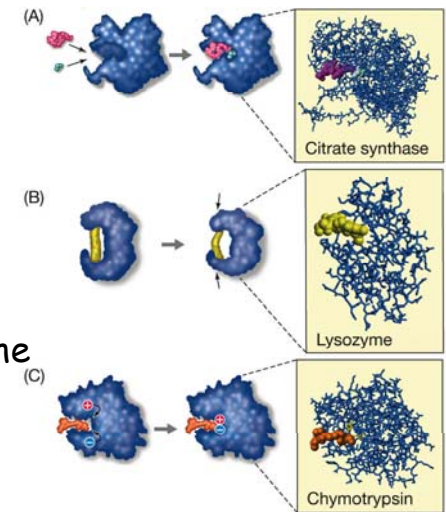


Catalytic mechanisms

Substrate is bound and orientated correctly

Stretching of chemical bonds may be induced by conformational changes in the protein

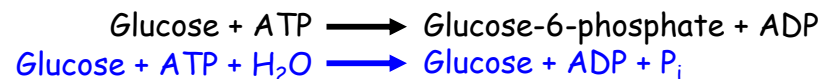
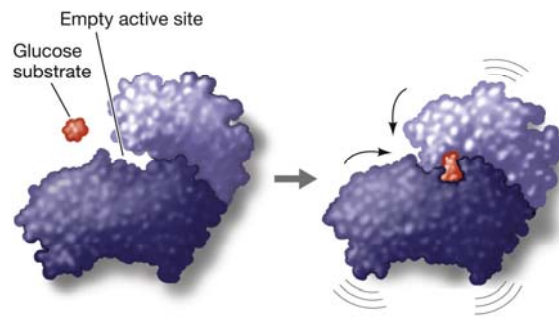
Transient modifications of the substrate:
acid-base
covalent
redox



Induced fit

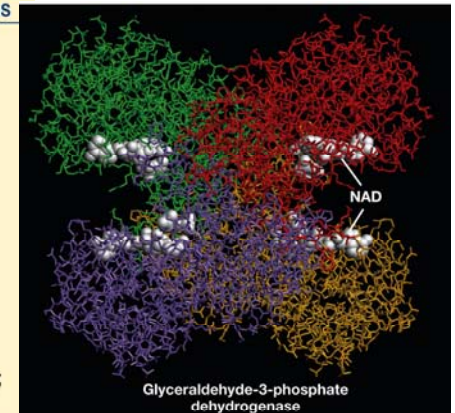
Change in conformation of the enzyme induced by substrate binding

In **hexokinase**, water is excluded from the active site by a conformational change. *This prevents water from acting as a phosphate acceptor instead of glucose*

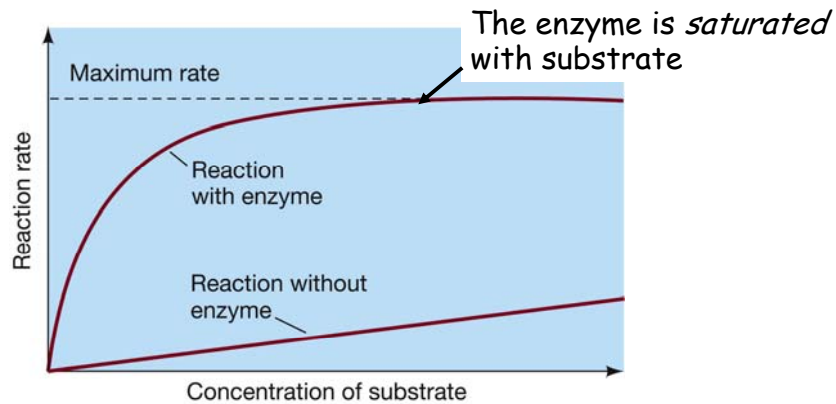


Many enzymes need cofactors, coenzymes or prosthetic groups for activity

TYPE OF MOLECULE	ROLE IN CATALYZED REACTIONS
COFACTORS	
Iron (Fe^{2+} or Fe^{3+})	Oxidation/reduction
Copper (Cu^+ or Cu^{2+})	Oxidation/reduction
Zinc (Zn^{2+})	Helps bind NAD
COENZYMES	
Biotin	Carries $-\text{COO}^-$
Coenzyme A	Carries $-\text{CO}-\text{CH}_3$
NAD	Carries electrons
FAD	Carries electrons
ATP	Provides/extracts energy
PROSTHETIC GROUPS	
Heme	Binds ions, O_2 , and electrons; contains iron cofactor
Flavin	Binds electrons
Retinal	Converts light energy



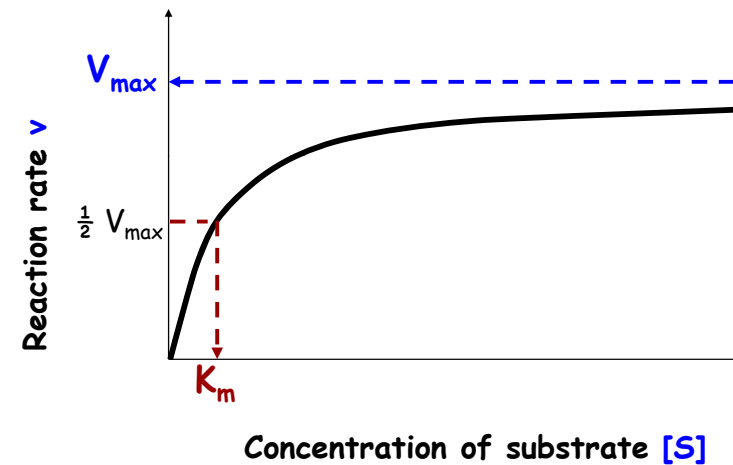
Rate of reaction is dependent on substrate concentration



Turnover number is a measure of enzyme effectiveness:
Lysozyme: transforms 0.5 substrate molecules per second
Catalase: transforms 40 000 000 substrate molecules per second



Enzyme activity can be described by the Michaelis-Menten model



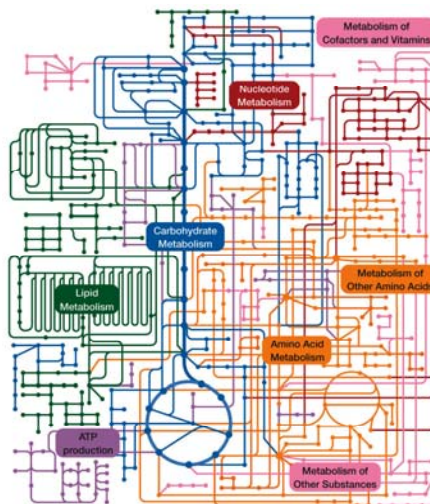
Regulation of enzyme activity

Homeostasis:
Maintenance of constant conditions

Inhibitors

Allosteric regulation

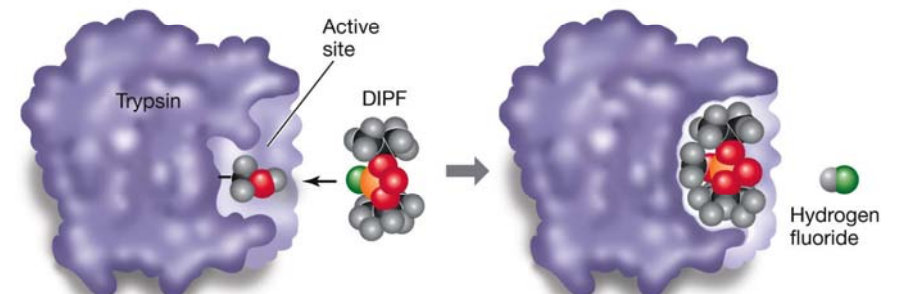
Environment



Irreversible inhibition

The enzyme is irreversibly inhibited and becomes catalytically inactive

Irreversible inhibition often involves covalent modification of amino acid side chains

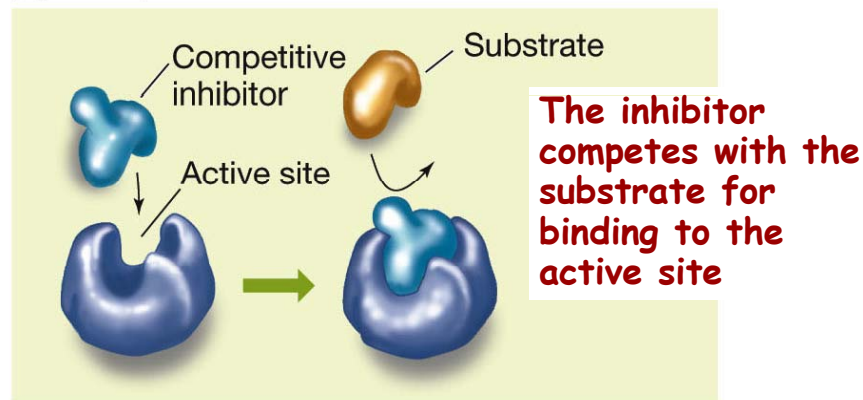


DIPF reacts with a OH-group of a serine in trypsin's active site



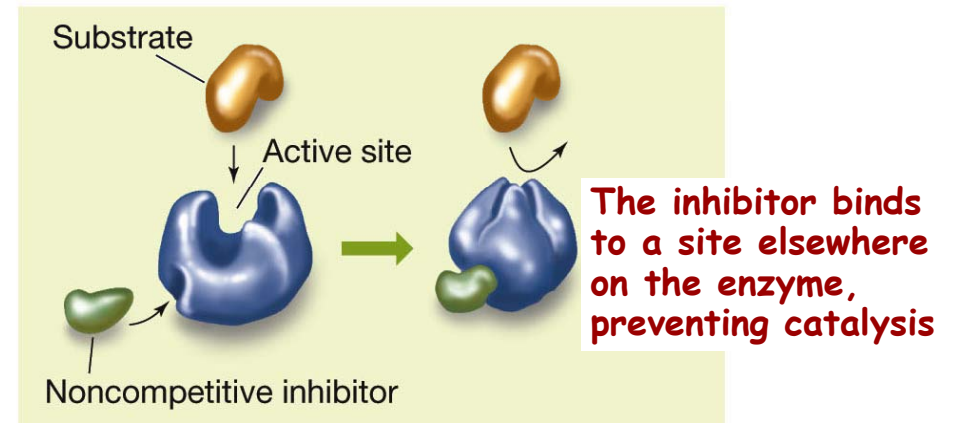
Reversible inhibition can be competitive or non-competitive

(A) Competitive inhibition



Reversible inhibition can be competitive or non-competitive

(B) Noncompetitive inhibition



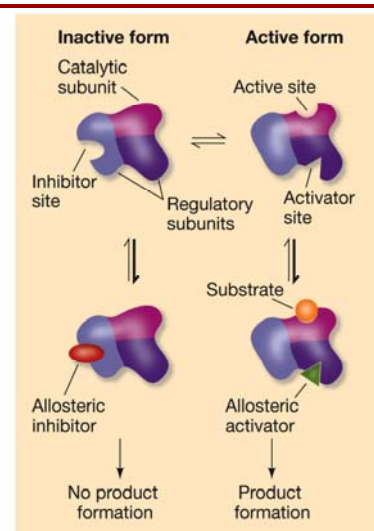
Allosteric regulation

Allosteric enzymes can switch between an **active** and an **inactive** form

The inactive form is stabilised by allosteric inhibitors

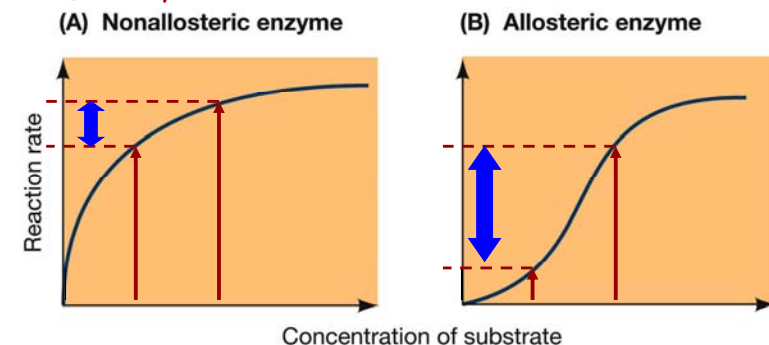
The active form is stabilised by allosteric activators

Allosteric inhibitors and activators bind to a regulatory site away from the active site

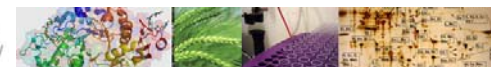


Allosteric regulation

Allosteric enzymes show **S-shaped (sigmoid)** reaction curves (ie they **DO NOT** conform to the Michaelis-Menten model)

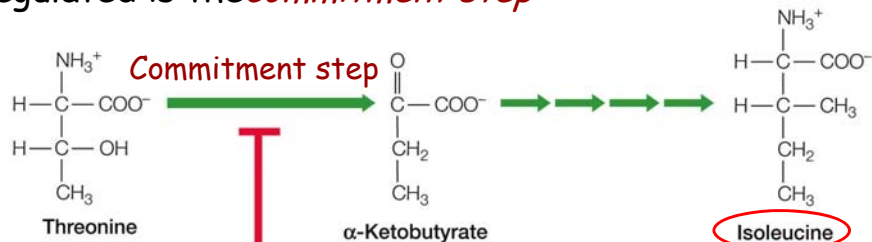


Consequence: The rate of reaction is extremely sensitive to changes in substrate concentrations. Allosteric enzymes are often important regulators of metabolic pathways



Feedback inhibition

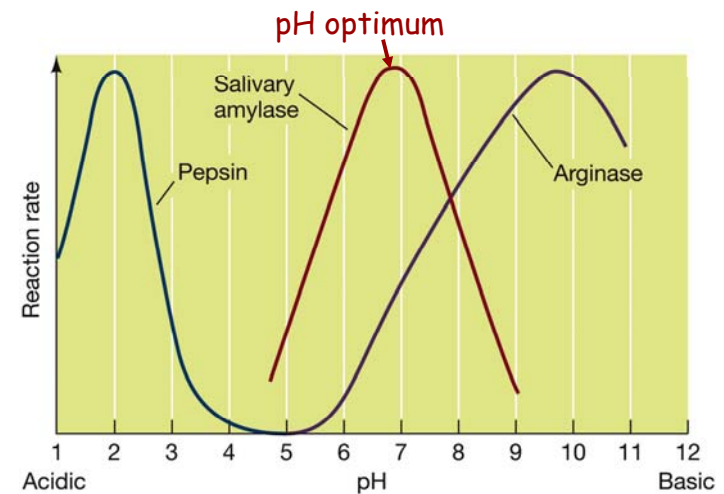
The typical point at which metabolic pathways are regulated is the *commitment step*



The end product of the pathway inhibits the enzyme at the commitment step of the pathway



Effect of pH on enzyme activity



Effect of temperature

